



COVER SHEET

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Abstract:

Access 5 analyzed the differences between UAS and manned aircraft operations under five categories of abnormal or emergency situations: Link Failure, Lost Communications, Onboard System Failures, Control Station Failures and Abnormal Weather. These analyses were made from the vantage point of the impact that these operations have on the US air traffic control system, with recommendations for new policies and procedures included where appropriate.

Key findings: Technologies and missions that are unique to unmanned aircraft systems necessitate new policies and procedures for UAS operations under abnormal/emergency situations. For example, the loss of UAS command and status data links are not addressed under existing rules for loss of two-way voice communications, rules primarily intended to address manned operations on point-to-point flights. Requirements for predictability of UAS operations under link failure as well as procedures for use of alternative communications methods should be incorporated into rules governing these situations. Similarly, due to UAS-unique sensitivity to icing and solar activity, new rules addressing UAS operations in abnormal weather conditions are also needed. But beyond UAS-unique aspects, existing policies and procedures for handling abnormal or emergencies situations for manned flights are applicable and appropriate for UAS operations.

Status:

WP – Work in Progress Draft

Limitations on use:

This document is an interim deliverable, representing thoughts and ideas of the Policy IPT, National Airspace System work package team. It has not been reviewed or approved as an Access 5 project position on this subject. It includes analysis on policies and procedures limited to abnormal and emergency enroute operations at and above FL430. Abnormal and emergency UAS operations below FL430, in terminal areas, as well as normal UAS operations were not addressed in this document. This information also needs substantiation through simulation and flight demonstrations, in addition to SEIT review and comment.

*Executive Summary***EXECUTIVE SUMMARY:**
Impact of UAS Emergency and Abnormal Events on the NAS.

This paper summarizes analysis and recommendations regarding the impact on the National Airspace System (NAS), and in particular on Air Traffic Control of unmanned aircraft (UA) experiencing abnormal or emergency conditions. The NAS Group of the Access 5 Policy IPT reviewed UA abnormal or emergency events to identify critical operational issues sorted into five areas: Link Failure, Lost Communications, Onboard System Failures, Control Station Failures, and Abnormal Weather Conditions.

KEY FINDINGS: From this analysis we found that, in many respects, UA responses to abnormal or emergency events would be similar to those on manned aircraft with a similar impact on the NAS. For example, most failures in UA onboard systems (e.g. flight controls, propulsion systems) would be treated by pilots and controllers much the same as analogous failures onboard manned aircraft. Similarly, failures in a UA control station would be handled much like comparable failures in a cockpit. So, in these areas, we foresee no significant changes to procedures or policies. However, failures involving UA-unique features such as control data link and long endurance loiter missions have no parallel in manned systems and may require new policies and procedures for UA pilots and ATC in the following areas:

Link Failure: Failure of control link, irrespective of loss of communications or payload link, generally results in UA reversion to autonomous (pre-programmed) operation and/or loss of aircraft status information. In this event, it is critically important that the UA's trajectory be highly predictable and that ATC be made aware of that trajectory sufficiently in advance to minimize adverse impact on other traffic. Existing regulations and procedures do not adequately address Link Failure or potential long duration, autonomous flight operation in the NAS. Notional Link Failure procedures were drafted (see Appendix 3) taking into account differences in UA autonomy, missions and operating flight altitudes. These procedures were developed for use in testing a policy question of whether or not a UA experiencing Link Failure should continue flight or land as soon as practicable. As of the date of this report these procedures had not yet been tested or validated and we recommend them for use in simulation and further studies on this subject.

Lost Communications: Two-way radio communications between a UA pilot and ATC are typically conducted by relay to the aircraft and then to ATC. In the event of loss of radio communications, there are several alternative methods of ground based communications available to the UA pilot such as telephone or data link. Existing ATC communications systems and current Lost Communications rules however do not have provisions for use of these systems. We recommend that 14 CFR Section 91.185 be reviewed not only to take advantage of new communications technologies, but also to address communications failures on long duration flights typical of HALE UAS.

Adverse Weather: In general, procedures for UA operations in adverse weather will be much the same as those for manned aircraft operating at similar slow airspeeds. However, given the potential significance of solar RF interference on UA control data links, information on solar activity should be incorporated into existing weather products available to all pilots.

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INTRODUCTION

Purpose

This position paper identifies critical issues regarding Unmanned Aircraft Systems¹ (UAS) operations in the National Airspace System (NAS) during emergency and abnormal events. The paper provides an analysis of the impact on the NAS and, in particular, on the Air Traffic Control (ATC) system during certain events: 1. UAS Link Failure, 2. Lost Communications, 3. Onboard Systems Failures, 4. Control Station Failures, and 5. Abnormal Weather Conditions. These emergency and abnormal events were analyzed to determine their uniqueness to UAS operations and to determine any requirements necessary to ensure compatibility of UAS operations with manned aircraft operations. Recommendations on policy and procedural changes, based on analysis and evaluation of these situations, are also included in this paper. It should be noted that

¹ While Access 5 has adopted the FAA's nomenclature for UA and UAS, note that a variety of other terms have been used for these types of aircraft, including Remotely Operated Aircraft (ROA), Remotely Piloted Aircraft (RPA), and Unmanned/Unpiloted Air Vehicle (UAV).

discussions and positions presented here are intended to address only High Altitude, Long Endurance (HALE) UAS, operating in accordance with instrument flight rules (IFR) and UAS receiving ATC services. Each of the failures discussed in this paper were treated as individual events, not accompanied by other failures. Multiple failures are addressed in a separate Access 5 Contingency Management paper. The impact of normal UAS operations on the NAS is being addressed in a separate Access 5 position paper.

Background

The Access 5 Policy Integrated Product Team, National Airspace System (NAS) Group authored this position paper. The NAS Group was tasked with evaluating the impact of UAS emergency and abnormal operations on the NAS, focusing initially on Step 1 of Access 5 covering unmanned aircraft operations at and above FL430. This task, initially divided into eight specific subject matters, was subsequently refined into the five emergency and abnormal events listed above and discussed below. As a result of meetings with the FAA, the scope was broadened beyond Step 1 to include operations below FL430.

The information presented in this paper was discussed and evaluated at numerous workshops attended by representatives from the National Aeronautics and Space Administration (NASA), Federal Aviation Administration (FAA), Department of Defense (DoD), Department of Homeland Security (DHS), UAS industry and academia. Comments and recommendations received during each of the workshops were reviewed and considered prior to finalizing the positions reflected in this paper.

The NAS is evolving, and part of that evolution will be new policies and procedures to accommodate the safe and routine operation of UAS in the NAS. We assume that the operation of UAS in the NAS will become routine at some point in the near future, and that such UASs will be certified by FAA to ensure high levels of safety and reliability.

Simulations

Airspace operations simulations were conducted in two phases, Normal Operations and Contingency Management Actions, to evaluate the effects UAS emergency and abnormal events would have on the ATC system. These simulations used data from the ATC Enhanced Traffic Management System with the addition of contingencies. Participants in the simulation exercises were ATC personnel who were briefed on procedures for handling UAS contingencies. At the conclusion of each simulation exercise, survey data was gathered and reviewed. Post-exercise discussions were also held with the ATC participants to capture their impressions of the events. Results from these simulations are provided in a separate paper from the Access 5 Simulation IPT.

1. LINK FAILURE

Unmanned Aircraft Systems comprises the Unmanned Aircraft (UA), the Aircraft Control Station (ACS) and Data Links, which include Control Links, Communications Links, and Payload Links. This section covers Link Failure (also known as Lost Link), which is the loss of the Control Link between the pilot² of a UAS and the aircraft under his control. For clarity, the terms “Link Failure” and “Link Interruption” are used here in lieu of “Lost Link”.

DISCUSSION

The pilot controls the UA from an ACS using a Control Link to command the aircraft and receive information from it via line of sight (LOS) or beyond line of sight systems (BLOS).

Control Links: There are two distinct components of the Control Link between the ACS and the UA: the Command Link and Status Link.

- a) **Command Link** - The Command Link is the method used to transfer the pilot’s intent to the aircraft. The pilot’s intent must follow a path that utilizes a number of components in a serial arrangement. The pilot moves a control or mouse in the ground station, the command goes from there to a processor, to an antenna, to the antenna on an aircraft, and then through the aircraft’s modems and processors until it arrives at the flight control surfaces on the aircraft. Command Link failure can be caused by the failure of any of these components. The command link may be temporarily lost during the course of a flight, e.g., geometry may cause a temporary satellite signal block due in part to the aircraft structure. In this case, the pilot may wait until the aircraft moves back into favorable coverage, or the aircraft may perform an autonomous action to resolve the problem. An adverse impact to the NAS and ATC could occur when there is an unexpected or uncoordinated UA maneuver.
- b) **Status Link** - The Status Link provides the pilot with UA health and status information. A loss of this link disrupts the pilot’s situational awareness, and the ability to determine the aircraft’s position and what it is doing. Alternate methods for a UA pilot to obtain status information, when the status link is lost, are quite limited. For example, the UA pilot may request that ATC verify the UA transponder is replying to radar interrogation, and that ATC provide the UA pilot with the current radar-displayed UA position and altitude. Another method is to use a manned chase aircraft to monitor the UA during flight. These methods increase the complexity, workload, and costs of UA operations such that they would not be practical or cost effective on a large scale.

² ‘Pilot’ means the individual that monitors, controls and maneuvers the UA through the real-time issuance of command and control input to the aircraft.

Terminology: For purposes of this discussion and for crafting notional Link Failure procedures (see Appendix 3), it was necessary to define terms addressing Link Failure. The following definitions are used in this paper and are recommended for usage in pilot/controller phraseology.

“Link” - A term referring to all electromagnetic links to and from unmanned aircraft which includes control, communications and payload links.

“Control Link”: The element of the unmanned aircraft system used by the UA pilot to fly the aircraft. Consists of the command link (uplink) and the status link (downlink).

- **“Command Link”:** The element of the unmanned aircraft system used to transfer a pilot’s intent to the unmanned aircraft. The uplink portion of the control link between a pilot and the unmanned aircraft.
- **“Status Link”:** The element of the unmanned aircraft system that provides a UA pilot with the operational status of the aircraft. The downlink portion of the control link between a pilot and the unmanned aircraft.

“Communications Link”: The element of the unmanned aircraft system used for voice and/or digital communications between a UA pilot and ATC. Includes an uplink and downlink component. Often implemented as part of the control link.

“Payload Link”: The element of the unmanned aircraft system used for control of payload equipment (e.g. cameras, sensors, deployable devices). Includes an uplink for control of payload equipment and a downlink for data collection.

“Link Interruption” – An occurrence when either the unmanned aircraft or the aircraft control station detects the loss of the command and/or status link. Link Interruption becomes Link Failure if the loss of link lasts longer than a predefined interval.

“Link Failure” – The loss of command and/or status link between a pilot and an unmanned aircraft.

UA Responses to Link Failure: UA flight plans and Link Failure contingency plans are loaded onboard the UA prior to flight. These contingency plans, which are executed after a pre-set Link Interruption time-period, may include reconfiguring onboard systems or maneuvering the UA to reacquire the link signal. Contingency flight plans will vary depending upon the UA level of autonomy, phase of flight, and nature of the mission.

- a) **UA Levels of Autonomy** - The current inventory of UAS respond differently to Link Failure situations depending on the level of autonomy of each system. From an ATC perspective, there are two main groups of UAS with regard to levels of autonomy: 1. pilot-in-the-loop systems which require link and direct pilot control to land the aircraft (e.g. Altair, Perseus, Helios), and 2. UAS capable of fully autonomous operations including auto-land (e.g. Global Hawk).
- 1) **Pilot-in-the-loop UAS Contingency Operations:** UAS that do not have the ability to auto-land are typically programmed to attempt to reacquire link by first reconfiguring onboard systems (e.g. receivers, antenna), then if unsuccessful maneuver the UA into a position to restore the link. If still unsuccessful in reacquiring the link, some existing UA pilot-in-the-loop systems are programmed to fly to a location where a UAS pilot lands the aircraft. If this option is not available, the UA may be let down to the ground via parachute, preprogrammed flight maneuver (ex: spiral descent to ground), or in-flight destruction (ex: explosive charge).
 - 2) **Fully Autonomous UAS Contingency Operations:** UAS that are capable of fully autonomous operations are also typically programmed to initially attempt to reacquire the link using methods similar to pilot-in-the-loop UAS. Failing that, these systems are capable of completing their mission and landing autonomously.
- b) **Phase of Flight** - Most UAS use a timing device initiated when Link Interruption is detected. Time parameters set for initiation of Link Failure operations may be quite short during flights at lower altitudes where UA mix with numerous other aircraft. Longer time parameters may be used for flights in very high altitudes where the UA may be on station for long missions with no other aircraft in that altitude stratum.
- c) **Nature of the Mission – In contrast to UA loitering missions**, point-to-point UA missions that experience Link Failure can be programmed to comply with existing Lost Communications procedures, notwithstanding the level of autonomy issues discussed above. Current UA Link Failure contingency operations are tailored for each mission and are individually coordinated with ATC. However, loitering missions (ex: orbiting for extended periods or flying mapping routes) experiencing Lost Communications or Link Failure present novel challenges to ATC for both manned and unmanned aircraft.

Critical Operational Issues

The following are critical operational issues considered in the framing of our recommendations for new policies and procedures.

A. Lost Communications rules don't address UA Link Failure operations: Link Failure situations are unique to UA operations and command link failures have no parallel in manned operations. Currently there are no regulations or procedures that adequately address Link Failure contingencies. Lost Communications procedures stipulated in Title 14 Code of Federal Regulations (14 CFR) Part 91.185 were developed to provide predictability of a flight's trajectory in the event pilot-to-ATC radio voice communications were lost. Lost Communication rules presume an onboard pilot can fly the aircraft, monitor aircraft systems, and if in VMC, "see and avoid" other traffic and proceed to an airport to land, assumptions which are not valid for UA operations.

B. Lost Communications rules don't address UA missions: The provisions of 14 CFR Section 91.185 primarily address flights operating under IFR from one airport to another airport. UA flights typically do not fly point-to-point, but rather fly to a pre-determined area where they may remain on station for many hours before returning to land. Original Lost Communications rules did not anticipate long duration missions remaining in the NAS after suffering a loss of voice communications or a loss of Control Link.

C. ATC clearance amendments cannot be programmed into UA Link Failure program: IFR flights are assigned specific routes and altitudes from ATC and may receive radar vectors or amendments to flight plans once airborne. UA pilots respond to ATC instructions in the same manner as onboard pilots. In the event of Lost Communications, pilots are required to comply with instructions assigned in the last ATC clearance received, including vectors, route changes, and even 'expect further clearance' changes. Most UAS, once airborne do not have the capability to be reprogrammed with revised Link Failure contingency routes in the event they receive alternate ATC instructions that change their filed routing.

D. UA course reversal to regain link is a serious problem for ATC: Some UA are programmed for a Link Failure contingency action to reverse course and climb to a higher altitude in an attempt to regain the link. This maneuver, without prior coordination with controllers, would present serious problems for ATC. Beyond the obvious problems of no-notice maneuvers, even if a controller is aware a UA is experiencing Link Failure and will make a turn, the controller needs to know the location and direction of that initial turn. Link Failure contingency programming may vary the location and direction of a turn depending on the initial heading of the aircraft, so this may not be known in advance by the UA pilot or the controller. Course reversal and/or altitude changes as an automatic response to a Link Failure situation would almost certainly not be acceptable to ATC.

E. Incorporating Link Failure contingency data into Flight Plans may be necessary but is problematic: Similar to current flight planning requirements for filing alternate

airport information, there may be value in including Link Failure contingency plans in UA filed flight plans. For example, in the case where a lengthy UA flight profile is changed automatically due to Link Failure, it is highly desirable that the new route information be available to controllers from the Host computer. Making this data available in the Host computer would preclude controllers having to manually enter lengthy route information into the Host and would help ensure the data is available to all ATC units that will work the UA. However, there are numerous limitations in the current Host (and in the initial version of the upcoming En Route Automation Modernization (FAA Web link), ERAM, system) that preclude entering flight plans containing multiple contingency routes for one UA flight. Coordination of UA Link Failure contingency flight plans between the UA pilot and ATC is critically important and some method must be devised for quickly and accurately exchanging this information.

F. Individual coordination of Link Failure contingency plans via the COA process is unworkable for large numbers of UA operations: Link Failure procedures for UA test flights to date have been developed under Certificates of Authorization (COA) with contingency plans tailored to and coordinated for each flight. This approach has been workable for small numbers of test flights but would not be manageable for the large volume of UA flights envisioned in the future.

G. Link failure and the likely loss of pilot situational awareness will result in increased pilot-controller communications. The pilot's need for aircraft position information from controllers (location and altitude of the UA based on ATC radar information) may create an unacceptable communications burden on the pilot and the controller. This scenario needs to be explored through simulation and flight test to assess the need for new rules or procedures to manage this aspect of link failure.

H. Transponder beacon codes are used to signal Lost Communications, but there is no corresponding way for a UA that has suffered Lost Communications and Link Failure to signal the double contingency. Use of a special code (7XXX) to signal Link Failure would serve to promptly alert ATC to this event, whether or not the pilot is able to communicate this failure to ATC.

Link Failure Principles

A general set of procedures, similar to existing Lost Communications procedures, is needed to govern Link Failure procedures covering a wide range of situations. Consistent with the Access 5 assumption of minimizing adverse impact on the NAS, the overarching principles for Link Failure procedures should be: 1) timely notification and coordination with ATC, and 2) predictable flight trajectory.

Timely notification and coordination with ATC: ATC can adapt to changes to UA flight plans if provided sufficient advance notice. Notice is needed not only to permit resolution of near-term traffic conflicts but also to coordinate the change in operational mode of a Link Failure UA with other ATC entities. Similar to

handling Lost Communications aircraft, ATC must make additional allowances for handling Link Failure aircraft in resolving traffic conflicts between aircraft under ATC control and those out of contact with ATC. As is the case with other significant in-flight failures, UA pilots should be required to notify ATC as soon as possible when experiencing Link Failure.

Predictable flight trajectory: As is the case with existing Lost Communications procedures, a critical objective of Link Failure procedures is to provide both the UA pilot and ATC with a highly predictable trajectory for the UA.

Contingency flight plans should not necessarily be predicated on early termination of the UA mission/flight. For example, a high altitude UA loiter mission experiencing Link Failure may be best handled by remaining at altitude for some time versus making a precipitous descent through traffic. On the other hand, continued operation of a UA in the NAS under Link Failure increases the workload of ATC in managing other traffic to avoid the UA. In addition, in the event of any subsequent onboard failures, e.g. in the propulsion or electrical system, the pilot will not only be incapable of controlling the UA but will even be unaware of the failure itself.

Notional Link Failure Procedures

Under Link Failure mode an unmanned aircraft operates according to onboard, pre-programmed instructions. In addition to being unable to command the aircraft in response to live ATC instructions, the pilot may also experience Lost Communications with ATC as a result of Link Failure.

With this in mind, the NAS group developed a set of notional Link Failure procedures (see) as a means of creating simulation scenarios to test potential approaches to Link Failure. These procedures were devised to supplant existing Lost Communications procedures, taking into account different UA aircraft capabilities, missions and operating flight altitudes. The overarching principle of these notional Link Failure procedures is that the UA's trajectory be highly predictable and that ATC is made aware of the UA's trajectory sufficiently in advance, to minimize adverse impact on other traffic.

These procedures were grouped in terms of their similarity to existing Lost Communications procedures (see Table 1 in Appendix 3). These procedures were also grouped under two potential policies: A. Continue the Mission after the Link Failure (Table 2), or B. Land As Soon As Practicable after the failure (Table 3).

RECOMMENDATIONS

The following are preliminary Access 5 recommendations³ for Link Failure contingency procedures, based on a review and assessment of current regulations and directives. Test results from simulations and flight operations conducted by Access 5 were planned to be assessed and factored into final recommendations.

1.1. Establish principles for Link Failure contingency procedures. For example, require timely notification and coordination with ATC and predictable flight trajectory.

1.2. Establish Link Failure regulations and procedures. These regulations and procedures should be validated through simulations and flight tests.

1.3 Require methods for including Link Failure contingency information in filed flight plans. Recommend that the upcoming ERAM system include capability for large flight plan data files.

1.4. Determine time intervals, as described in Appendix 3, for proposed Link Failure procedures. These time intervals should be validated through simulations and flight tests.

1.5. Investigate use of beacon codes to signal occurrence of Link Failure and contingency maneuver(s) to ATC. See [discussion of alternate methods of communication](#) in Section.

1.6. Investigate the feasibility of a method for the pilot to upload ATC clearance amendments from the Aircraft Control Station to the UA onboard contingency program as these amendments are issued by ATC. See Notes 4 and 6, Appendix 4: Paths Not Taken.

³ The Access5 Project was originally a 5-year effort with four steps for introducing routine access of UAS in the NAS. Recommendations shown in this report were based on work completed as of January 2006, focused primarily on Step 1. Further analysis and testing were planned prior to making final recommendations.

2. LOST COMMUNICATIONS

This section covers critical operational issues regarding the loss of two-way radio voice communications between pilots of UAS and ATC.

BACKGROUND

Two-way radio communications between a UA pilot and ATC are typically conducted either by line of sight radio relay from the Aircraft Control Station (ACS) to the aircraft and then to ATC, or via a data link channel that may include a satellite relay link for beyond line of sight operations. In the latter case, UAS loss of data link may also result in a loss of voice communications with ATC.

UA pilots in ACS typically have access to a ground based, or land line, voice communications systems, such as telephone, that are not currently available to airborne pilots. Some UAS have the added capability, in the event of losing two-way radio communications, of switching the command, control and communication function of the UAS to another ACS to provide two-way communications capability with ATC.

Current Lost Communications Regulations/Procedures

Regulations for manned aircraft experiencing loss of two-way radio communications are detailed in Title 14 Code of Federal Regulations (14 CFR) Section 91.185, IFR operations: Two-way radio communications failure. ATC procedures addressing this matter are contained in FAAO 7110.65. Standard operating procedures for pilots are detailed in the (AIM).

During flight training, pilots are taught several methods for reestablishing two-way radio communications with ATC. For example:

- attempt contact by returning to the previously assigned ATC frequency
- attempt contact with a Flight Service Station or Aeronautical Radio/Incorporated
- monitor those navigational aid facilities that have a feature for voice communications broadcasts from ATC
- use emergency frequencies (121.5/243.0) to try to contact ATC
- relay information to ATC through radio contact with other pilots or company operations personnel.

In the event the above actions prove unsuccessful, the pilot of a transponder equipped aircraft should communicate the loss of two-way radio communications to ATC by changing the transponder beacon code to 7600 or by flying left or right triangular patterns to signal the type of failure.

Currently, 14 CFR Section 91.185 also requires a pilot to follow the flight plan if in instrument meteorological conditions (IMC), or if in visual meteorological conditions (VMC) remain in VMC if able and land as soon as practicable. Existing UAS are not equipped to sense and maintain flight within VMC and so they are programmed to continue flight with lost communications following provisions covering operations under IMC.

Alternate Methods of Communications

Existing regulations and ATC procedures on lost communications are predicated on the loss of radio communications between a pilot in an aircraft cockpit and a ground based air traffic controller. The promulgated regulation (Section 91.127 since codified as Section 91.185) and associated ATC procedures were issued years before the advent of current communications technologies such as cellular telephones and data link. Neither the current regulation nor procedures have been modified to take advantage of these new communications systems.

Comparison of Manned/Unmanned Aircraft to ATC Communications Systems

Manned Aircraft	HALE Unmanned Aircraft (UA)
Voice communications between pilot and ATC via direct air-to-ground system on most aircraft.	Voice communications between pilot and ATC via relays from control station to aircraft and/or satellite, then to ATC.
Transponder on most aircraft.	Transponders on all UA.
VOR Voice receiver on most aircraft.	Not available in current systems.
Command Link not available on manned aircraft.	Command link available on all UA.
Cellular phones on board some aircraft. Not approved for routine access to land based telephone systems.	Aircraft Control Station (when located on the ground) has access to the ground based telephone system.

Telephone Communications – Telephone communications (either landline or cellular) between UA pilots and ATC have been used as a backup option to radio communications, but use of this option is problematic for several reasons.

1. Normally, controllers receive voice communications via headset and/or a speaker connected to ATC radio and interphone communications systems. Commercial telephone communications are not typically routed into these systems. In most cases, telephone contact between the UA pilot and ATC is made through an intermediary, such as the Operations Supervisor, Traffic Management Supervisor, or other FAA facility contact. This person then relays the information to the controller then back to the pilot. This process is cumbersome, time consuming and introduces the potential for communications error.

2. In many large ATC facilities, there are provisions for routing telephone circuits to controllers' headsets, but this can be disruptive and distracting for the controller. Telephone communications do not permit situational awareness (e.g. party line) as is the case with two-way radio communications between controllers and pilots using ATC radio frequencies. The capability for routing telephone communications into headsets is not currently available in all ATC facilities.
3. While use of telephone is workable for infrequent usage, it would be unmanageable for a large numbers of calls. Extensive use of the telephone for pilot/ATC communications would require listing appropriate phone numbers to call the appropriate ATC facilities and UA Aircraft Control Stations. Regular use of telephone communications would in effect require the creation of a communications system in parallel to the existing ATC radio frequency communications system – no small task.

Transponder – Currently, a transponder is used by ATC to establish/verify an aircraft's identity or position. Pilots, on the other hand, can use a transponder to signal an emergency or radio malfunction. One concept being considered is to use a transponder as an alternate communications method whereby a UA pilot would use a very limited set of ATC beacon codes (similar to the one used to indicate a radio malfunction) to signal not only Lost Communications but also signal what contingency a UA is executing. For example, a UA experiencing Link Failure with Lost Communications would squawk beacon code 7700 for one minute, 7XXX for 15 minutes, and then repeat, to inform ATC of the failure and of the contingency maneuver(s) being executed. Specific codes for UA contingency plans would need to be set aside under the National ATC Beacon Code Allocation Plan to make this option viable.

CRITICAL OPERATIONAL ISSUES

Overall, the loss of two-way radio communications between a UA pilot and ATC will have the same impact as losing two-way radio communications between a manned aircraft and ATC. However, current lost communications regulations focus on point-to-point flights and do not adequately address long duration and/or loitering missions, manned or unmanned. Since a large percentage of UA missions will be long duration, this may become a significant issue for ATC.

RECOMMENDATIONS

The below recommendations are offered to lessen the impact caused by a loss of two-way radio communications between a UA pilot and ATC.

2.1. All UA operating IFR must be able to comply with the requirements specified in 14 CFR Section 91.185.

2.2. All UA should be equipped with an altitude encoding transponder capable of squawking ATC beacon code 7600 when there is a loss of two-way radio communications with ATC.

2.3. The FAA should review 14 CFR Section 91.185 to ensure that the regulation meets current NAS requirements, for example, takes advantage of current and future communications technologies (ex: cellular phones, Controller Pilot Data Link Communications (CPDLC), Next Generation Communications (NEXCOM), and other non air-to-ground communications methodologies). In addition, Section 91.185 should be reviewed to address long duration and/or loitering missions.

3. CONTROL STATION FAILURES

This section covers critical operational issues related to UAS Aircraft Control Station abnormalities and their impact on operations in the NAS.

Background

Unmanned Aircraft (UA) operations are unique in the National Airspace System (NAS), in that these aircraft operate without a pilot physically onboard. The ground-based UA pilot controls the aircraft from an Aircraft Control Station (ACS) using a control link to issue commands and receive information from the aircraft. A total or partial loss of functionality in the ACS could limit the ability of the UA pilot to send commands, receive information to/from the UA, and may also result in the loss of two-way voice communications with ATC.

Aircraft Control Stations

Currently, ACS are configured to use either manual (pilot-in-the-loop) remote control, autonomous control, or some combination of both as a method for pilot control of the UA.

- **Manual (pilot-in-the-loop) remote control operations** – The pilot controls the UA directly via uplink during taxi, takeoff, and landing. Data is down linked to the ACS providing the pilot with UA system health and status information as well as situational awareness during normal and emergency operations. During the en route phase of flight, the UA pilot can either directly command movement of the aircraft via the UA flight control surfaces or send commands to the autopilot.
- **Autonomous Control operations** – In this mode the UA pilot typically sends only start, taxi, takeoff and stop commands. Once airborne, the UA follows a preplanned mission route unless an override command is received from the UA pilot. Typically, some contingency management functions are included in the programmed mission plan but these generally require concurrence from the pilot. The UA transponder can be pre-programmed to switch to the appropriate code in the event of a link failure or lost communication situation.

DISCUSSION

Complete Aircraft Control Station Failure: A complete ACS failure would result in a link failure and loss of two-way voice communications with ATC unless another ACS is available to take control of the UA. A complete ACS failure could result in a lengthy

period of lost communications pending transfer of communications to a backup ACS. ATC may not be aware that link failure was caused by an ACS failure but should be advised of this by the UA pilot as soon as possible.

Autonomous UAs have the capability of being pre-programmed to fly a contingency routing that includes landing at a designated UA airport. A total ACS failure should not impact these UAs' ability to land safely, assuming no other problems occur. Manual (pilot-in-the-loop) platforms, on the other hand, require a functioning ACS (Landing and Recovery Element) at the intended destination airport in order to ensure a safe landing. If a functioning ACS is not available at a designated airport and the UA is operating in a link failure contingency mode, alternate communications must be established between ATC and the UA pilot to determine the appropriate course of action. This situation could require extensive coordination to ensure safe recovery of the aircraft.

Partial ACS Failure: Partial ACS failure may occur for several reasons: hardware/software malfunction, power interruption, weather, etc., some of which may be temporary. Primary ATC voice communications may be impacted but establishing alternate voice communications using landline or cellular telephone may be possible (see earlier section on Lost Communications). A partial ACS failure may or may not result in a Link Failure (also discussed earlier). If the partial failure did not cause the UA to change to a Link Failure contingency operation, then the pilot should contact ATC to coordinate the appropriate course of action.

If the UA pilot has no control over a manual (pilot-in-the-loop) UA, ATC will likely handle this situation the same as an incapacitated pilot of a manned aircraft since the UA will likely not be flying a pre-programmed route. Controllers would probably provide a buffer of airspace between the UA and other aircraft to ensure a safe environment. Inability to receive UA status information at the ACS would also require additional coordination between ATC and the UAS pilot. For example, ATC would likely be requested to provide the pilot with UA position and altitude, based on radar display information, increasing the controller's workload significantly.

The best remedy in the event of partial or total ACS failure would be for control of the UA to be transferred to another functioning ACS as soon as possible. For ATC planning purposes, controllers should be promptly advised if a UAS pilot will be transferring control of a UA to another station. If there is a partial loss of an ACS and transfer to another station is not possible, ATC needs to be advised of what functionality has been lost. If the UA does not revert to a Link Failure contingency flight plan, ATC may need to provide additional separation between the UA and other aircraft to ensure the safety of nearby aircraft.

CRITICAL OPERATIONAL ISSUES

After a review of UA operating procedures and ACS failure modes, we found that the impact on ATC of partial or complete failure of an ACS is at a higher level than impacts described in the Link Failure and Lost Communications sections of this paper.

RECOMMENDATION

3.1 If the UAS allows for the diagnosis of the nature of the problem and the likely duration of the outage, this information should be communicated to ATC.

4. ONBOARD SYSTEMS FAILURES

This section covers critical operational issues related to UA onboard system failures, exclusive of Link Failure, and their impact on operations in the NAS.

BACKGROUND

UA Onboard System Failures have been outlined in seven categories in the Access 5 Contingency Management Requirements Document. The categories cover failures in the: Propulsion System, Power System, Flight Control System, Navigation System, Sensor and Payload System, Cooperative Collision Avoidance (CCA) System, and Mechanical and Other Systems. In these seven categories, the common requirement outlined by the Access 5 Contingency Management Group is that unmanned aircraft system (UAS) performance during onboard system failures “shall be mitigated in such a manner that the aircraft will be recoverable and/or will not cause loss of life or damage to property.” While the above categories have been identified in the Access 5 Contingency Management Document, they are not meant to be all-inclusive.

Current Regulations/ATC Procedures

Currently, there are no specific regulations that address UA onboard system failures. Because of the infinite variety of possible emergency situations, specific regulations or procedures cannot be prescribed. However, to lessen any impact on the ATC system, the pilot of a UA should comply with existing regulations detailed in Title 14 Code of Federal Regulations (14 CFR) to inform ATC of any onboard system failure and the type of assistance needed. Specifically, 14 CFR Sections -- 91.7, Civil aircraft airworthiness; 91.187, Operations under IFR in controlled airspace: Malfunction reports; 91.205, Powered civil aircraft with standard category U.S. airworthiness certification: Instrument and equipment requirements; and 91.213, Inoperative instruments and equipment.

DISCUSSION

UA pilot responses to onboard systems failures may differ from pilot responses to similar failures onboard manned aircraft. However, ATC responses to these failures generally would be no different than ATC handling of similar failures on manned aircraft, particularly for failures in flight controls, navigation and mechanical systems. For example, once advised by the pilot that a UA is experiencing flight control failure, ATC would clear other traffic away from the path of the UA just as it would for a manned aircraft.

For other failures, such as in propulsion systems and electric power systems, the ATC response would be the same as for manned aircraft, but controllers must be aware of

UAS-unique consequences of these failures. In event of propulsion system failure, some UAs are programmed to fly the aircraft to a designated UA airport or set down point within a preset time (e.g. 45 minutes for Global Hawk). In this instance, after loss of propulsion system and thus the generator, there is finite period of time after which the battery will be exhausted, leading to complete failure of all systems. This is a critical condition for a UA because there is no manual backup for operation of flight controls as there is on manned aircraft. ATC awareness of these contingency options coupled with good communications between the UA pilot and ATC are critically important to successful resolution of these onboard system failures. But no new procedures are envisioned here for ATC.

For some UAS-unique onboard systems such as sensor and payload systems, failures may require little or no ATC response. Loss of Control Link however may necessitate new pilot and controller procedures, such as those as described in the Link Failure section of this paper. Regarding failure of Flight Termination Systems, which are present on some UAS, the airworthiness certification process and requirements for UA reliability, should obviate the need for flight termination systems in the first place, so we do not anticipate any new procedures here (see Note 2, Appendix 4: Paths not Taken). We did not explore impact of failure of Cooperative Conflict Avoidance systems.

CRITICAL OPERATIONAL ISSUES

The Access 5 Policy IPT, NAS Group reviewed each of the seven failure categories outlined in the Access 5 Contingency Management Requirements Document. From this review we concluded that UA onboard system failures could in some cases have an adverse impact on NAS operations, but from a NAS perspective the impact would not be significantly different from that of a manned aircraft experiencing similar failures. UA onboard system failures would be treated by ATC as an emergency or a potential emergency in the same manner as ATC would respond to similar failures onboard a manned aircraft.

RECOMMENDATIONS

We make no new recommendations specifically regarding policies or procedures governing onboard system failures beyond those made elsewhere in this document. As with a manned aircraft, good communications between the UA pilot and ATC are of paramount importance to resolving these situations with minimum impact to the NAS.

5. ADVERSE WEATHER CONDITIONS

This section covers critical operational issues and the impact adverse weather phenomena have on UA operations in the NAS.

BACKGROUND

It is the pilot's responsibility to flight plan or maneuver around adverse weather based upon observed or provided weather information. As with manned aircraft, a UA must have the ability to avoid adverse weather. Most UA however do not have onboard weather sensing systems. While some environmental sensing systems may be available, contingency management for weather avoidance depends largely on the UA pilot's weather situational awareness gained from external sources. If certain UA are susceptible to icing conditions or must avoid significant turbulence, the certification process will take these matters into consideration and appropriate caveats will be detailed on the aircraft airworthiness certificate.

DISCUSSION

HALE UA operations will be conducted, for the most part, at altitudes typically used by high performance turbine aircraft. This in itself is not an issue. The challenge is how best to manage HALE UA operations when there is adverse weather in their area of operations, either en route or while loitering due to a mission profile. When there are adverse weather systems in a specific area, ATC adjusts traffic flows and initiates other traffic management solutions that are dynamic and require immediate pilot response. The presence of UAs in airspace subject to severe weather avoidance plan (SWAP) operations can make traffic management difficult. This is because some UAs operate at significantly slower speeds than other aircraft operating in the same airspace, potentially limiting traffic management options available to ATC during SWAP operations.

At times, ATC may have to manage operations by vectoring flights in a line, single file, several miles in-trail around known adverse weather. An en route UA may not be able to operate in this "line" of aircraft due to its slower speed, particularly in ATC sectors with a combination of limited airspace and adverse weather. So some UA missions and UA performance may require, in some cases, routings to avoid fast moving weather systems. Integrating these UA with other aircraft under these conditions may have an adverse impact on the NAS.

CRITICAL OPERATIONAL ISSUES

A. UA Performance/Missions – As stated above, a good part of the discussion on weather issues surrounds UA performance and the uniqueness of their missions. With the

advantage of being able to access and view weather products not available to onboard pilots. UA pilots and mission planners should look at options to avoid frontal activity areas. For example, a UA pilot could plan to delay entry into an area of adverse weather or, if airborne/or on station, the pilot should have the ability to depart the area or climb above the weather. Since these aircraft operate at slow speeds, a UA pilot could elect to circumnavigate the weather area far earlier than a manned aircraft so as to avoid the exodus around the weather area. In addition, UA may be able to operate in weather conditions that manned aircraft would normally avoid. In these cases, this may actually assist ATC.

B. Turbulence (weather related) - Through the certification process UA airframes should be expected to manage the effects of weather related turbulence in a manner comparable to manned aircraft. Aircraft-generated turbulence is not a weather issue and will be addressed in a separate position paper.

C. Icing – As a part of pre-flight planning, all pilots must consider icing conditions at the altitudes along their planned route of flight. Any caveats dealing with UA icing will be addressed, just as with a manned aircraft, as part of the certification process. The effect of icing on UAS will be addressed in a separate position paper.

D. Solar Activity – Many communications systems use the ionosphere to reflect radio signals over long distances. During solar storm activity many air-to-ground and ground-to-air communications may be adversely impacted. While the impact of solar flares may have some impact on ATC, the impact on unmanned aircraft could be critical. The main concern is the fact there is no pilot on board these aircraft to fly them if they lose radio communication. While significant solar storm activity is relatively rare, it has realistic capability to wipe out all link capability and some navigational equipment. Specifically, solar flares occur in three different classes, C, M, and X. The most severe is X, which will have definite radio and navigational effects, especially at higher latitudes. Radios could become completely unusable during an X solar flare storm and it will affect the accuracy of auto-landing systems. Solar flare activity may cause Global Positioning System (GPS) information to be unreliable. It can also affect the use of “over the horizon” HF radars that are used to detect and track aircraft. Some other significant solar effects that can have the same devastating effects are coronal mass ejections, sudden ionospheric disturbances, shortwave radio fadeouts, and radio bursts. The actual impact of solar activity on UA operations will be dependent upon the frequencies being used and the type of navigation systems being used by the UA. This is planned to be addressed in a separate Access 5 position paper.

RECOMMENDATIONS

5.1 Existing weather products, which include forecasts of turbulence and icing, should be expanded to include solar activity forecasts.

5.2 Adverse solar activity should be included in FAA pilot weather products such as Significant Meteorological reports (SIGMETs).

Appendix 1 14 CFR Section 91.185

§ 91.185 IFR operations: Two-way radio communications failure.

(a) General. Unless otherwise authorized by ATC, each pilot who has two-way radio communications failure when operating under IFR shall comply with the rules of this section.

(b) VFR conditions. If the failure occurs in VFR conditions, or if VFR conditions are encountered after the failure, each pilot shall continue the flight under VFR and land as soon as practicable.

(c) IFR conditions. If the failure occurs in IFR conditions, or if paragraph (b) of this section cannot be complied with, each pilot shall continue the flight according to the following:

(1) Route.

- (i) By the route assigned in the last ATC clearance received;
- (ii) If being radar vectored, by the direct route from the point of radio failure to the fix, route, or airway specified in the vector clearance;
- (iii) In the absence of an assigned route, by the route that ATC has advised may be expected in a further clearance; or
- (iv) In the absence of an assigned route or a route that ATC has advised may be expected in a further clearance, by the route filed in the flight plan.

(2) Altitude. At the highest of the following altitudes or flight levels for the route segment being flown:

- (i) The altitude or flight level assigned in the last ATC clearance received;
- (ii) The minimum altitude (converted, if appropriate, to minimum flight level as prescribed in §91.121(c)) for IFR operations; or
- (iii) The altitude or flight level ATC has advised may be expected in a further clearance.

(3) Leave clearance limit.

(i) When the clearance limit is a fix from which an approach begins, commence descent or descent and approach as close as possible to the expect-further-clearance time if one has been received, or if one has not been received, as close as possible to the estimated time of arrival as calculated from the filed or amended (with ATC) estimated time en route.

(ii) If the clearance limit is not a fix from which an approach begins, leave the clearance limit at the expect-further-clearance time if one has been received, or if none has been received, upon arrival over the clearance limit, and proceed to a fix from which an approach begins and commence descent or descent and approach as close as possible to the estimated time of arrival as calculated from the filed or amended (with ATC) estimated time en route.

[Doc. No. 18334, 54 FR 34294, Aug. 18, 1989; Amdt. 91-211, 54 FR 41211, Oct. 5, 1989]

Appendix 2 Glossary

Purpose: This glossary was compiled to promote a common understanding of terms used by the members of the Access 5 Group during their effort to integrate Unmanned Aircraft into the National Airspace System (NAS).

AIRCRAFT CONTROL STATION (ACS) – The equipment from which the pilot of an unmanned aircraft (UA) remotely controls and monitors the UA flight and mission activity.

AUTONOMOUS OPERATIONS – The method whereby the control of an unmanned aircraft is accomplished by an onboard self-contained flight management control system using previously inserted data.

CERTIFICATE OF WAIVER OR AUTHORIZATION (COA) - An FAA grant of approval for a specific operation, for a specified time period.

COMMAND LINK - The element of the unmanned aircraft system used to transfer a pilot's intent to the unmanned aircraft. The uplink portion of the control link between a pilot and the unmanned aircraft.

COMMUNICATIONS LINK - The element of the unmanned aircraft system used for voice and/or digital communications between a UA pilot and ATC. Includes an uplink and downlink component. Often implemented as part of the control link.

CONTROL LINK - The element of the unmanned aircraft system used by the UA pilot to fly the aircraft. Consists of the command link (uplink) and the status link (downlink).

COOPERATIVE SENSE AND AVOID SYSTEM (CSAS) – A system capable of communicating with systems on board other aircraft, or other airborne objects in order to facilitate detection or coordinate resolution maneuvers, or both.

FLIGHT TERMINATION SYSTEM – A device or pre-planned course of action that is used when continued safe flight is impractical.

HIGH ALTITUDE LONG ENDURANCE (HALE) – An unmanned aircraft capable of performing the mission objectives at an altitude of 40,000-foot mean sea level (MSL) or higher with sufficient cruise capability to transit the NAS.

HOLDING – A predetermined maneuver that keeps aircraft within a specified airspace.

LATENCY - The time incurred between two particular interfaces. The total latency is the delay between the true time of applicability of a measurement and the time that the measurement is reported at a particular interface (the latter minus the former).

LINK - A term referring to all links between an unmanned aircraft and the aircraft control station. It includes control, communications and payload links..

LINK FAILURE – The loss of command and/or status link between a pilot and an unmanned aircraft.

LINK INTERRUPTION – An occurrence when either the unmanned aircraft or the aircraft control station detects the loss of the command and/or status link. Link Interruption becomes Link Failure if the loss of link lasts longer than a predefined interval.

LOST COMMUNICATIONS – Loss of the ability to communicate by radio.

PAYLOAD LINK - The element of the unmanned aircraft system used for control of payload equipment (e.g. cameras, sensors, deployable devices). Includes an uplink for control of payload equipment and a downlink for data collection.

SEE AND AVOID– When weather conditions permit, pilots operating on instrument or visual flight rules are required to observe and maneuver to avoid other aircraft. Right-of-way rules are contained in 14 CFR part 91.

SENSE AND AVOID – The ability to detect conflicting object(s) and take the appropriate action to avoid a collision with said object(s).

STATUS LINK – The element of the unmanned aircraft system that provides a UA pilot with the operational status of the aircraft. The downlink portion of the control link between a pilot and an unmanned aircraft.

TRAFFIC ALERT AND COLLISION AVOIDANCE SYSTEM (TCAS) - Airborne collision avoidance system based on radar beacon signals which operates independent of ground-based equipment.

TRANSPONDER – The airborne radar beacon receiver/transmitter portion of the Air Traffic Control Radar Beacon System that automatically receives radio signals from interrogators on the ground, and selectively replies with a specific reply pulse or pulse group only to those interrogations being received on the mode to which it is set to respond.

UNMANNED AIRCRAFT SYSTEM (UAS) – An unmanned aircraft and its associated elements required for operation, including the various links and aircraft control station.

Appendix 3 Notional Link Failure Procedures

In each Link Failure case, the procedure begins at the time the UAS senses lost reception of link information, even momentarily. This event serves as the start of Link Interruption, which may be the result of a hardware/software malfunction, satellite signal interruption/blockage, weather or some other temporary condition. Once Link Interruption is detected onboard the UA, a timing device begins a countdown to trigger initiation of UA Link Failure contingency action(s) if the link is not re-established before the end of a pre-set time-period.

The following tables represent our initial attempts to sketch potential procedures that would help standardize the actions required of UA pilots and ATC controllers in the event of Link Failure. The Green/Yellow/Red encoding described in Table 1 represents three strategies for Link Failure procedures

Green: Similar to current Lost Communications Procedure.

Example scenario – link failure during high altitude loiter mission.

Response - The UA responds essentially the same as a manned aircraft operating under Lost Communications rules.

Yellow: Modified Lost Communications Procedure. (Only applicable under a policy of ‘Land as soon as practicable’).

Example scenario – link failure during terminal airspace orbit.

Response - The UA discontinues orbit maneuvers and proceeds to recovery point via previously cleared route.

Red: Urgent Reaction Procedure.

Example scenario – link failure on final approach to landing.

Response – urgent reaction procedure. The UA discontinues approach and proceeds to recovery point.

Tables 2 and 3 describe procedures predicated on a policy of either Continue Mission or a policy of Land As Soon As Practicable.

The times and procedures presented were an initial effort to categorize procedures for dealing with Link Failure. It is intended that these procedures and time intervals be tested in simulation and flight operations prior to finalizing recommendations for Link Failure procedures.

THREE GROUPS OF NOTIONAL LINK FAILURE PROCEDURES

Description	Time between start of Link Interruption Mode and start of Link Failure Mode	Time between start of Link Failure Mode and Execute Contingency Plan
Similar to current Lost Comm (91.185) procedure	Terminal - 10 seconds Enroute - 1 minute	15 minutes
Modified Lost Comm procedure	Terminal - 10 seconds Enroute - 1 minute	15 minutes
Urgent reaction procedure, in terminal airspace only (Access 5, Steps 3 and 4)	Terminal - 10 seconds	3 minutes

	Contingency Plans
	Route: Via last route assigned by ATC, which may be full mission route including flight planned orbits/loitering. Altitude: Initially maintain or continue climb/descent to last ATC assigned altitude. Then comply with 91.185 altitude rules to recovery point.
	Route: Discontinue any loiter/orbit, then rejoin last route assigned by ATC. Proceed to recovery point via cleared route without further loiter/orbit delays. Altitude: Initially maintain or continue climb/descent to last ATC assigned altitude. Then comply with 91.185 altitude rules to recovery point.
	Route: Maintain present heading for 3 minutes then turn direct to recovery point. Altitude: Comply with 91.185 altitude rules to recovery point.

Table 1 – Groups of Link Failure Procedures

UAS Link Failure Procedures– **POLICY A: CONTINUE MISSION**

CASE	UA Autonomy	Mission	Stratum	Link Failure Procedures
ACCESS 5		STEP ONE		
A1	Fully Autonomous – autoland capable.	Loiter/Orbit	Enroute	<ul style="list-style-type: none"> ▪ Time: 0:00 Link Interruption Mode Starts ▪ Time: 1:00 Link Failure Mode Starts¹– ATC Advised² ▪ Time: 16:00 Execute Contingency Plan: Comply with 91.185, proceed to recovery point. Transponder change to code 7xxx
A2	Fully Autonomous -autoland capable.	Point-to-Point	Enroute	▪ same as for Case A1
A3	Non autoland capable.	Loiter/Orbit	Enroute	▪ same as for Case A1
A4	Non autoland capable.	Point-to-Point	Enroute	▪ same as for Case A1
ACCESS 5		STEPS TWO, THREE AND FOUR		
A5	Fully Autonomous – autoland capable.	Loiter/Orbit	Terminal	<ul style="list-style-type: none"> ▪ Time: 0:00 Link Interruption Mode Starts ▪ Time: 0:10 Link Failure Mode Starts¹– ATC Advised² ▪ Time: 15:10 Execute Contingency Plan: Comply with 91.185, proceed to recovery point. Transponder change to code 7xxx
A6	Fully Autonomous – autoland capable.	Point-to-Point	Terminal	-same as for Case A5
A7	Non autoland capable.	Loiter/Orbit	Terminal	-same as for Case A5
A8	Non autoland capable.	Point-to-Point	Terminal	<ul style="list-style-type: none"> ▪ Time: 0:00 Link Interruption Mode Starts ▪ Time: 0:10 Link Failure Mode Starts¹– ATC Advised ▪ Time: 3:10 Execute Contingency Plan: Maintain present heading for 3 min then turn direct and proceed to recovery point. Maintain higher of: last assigned altitude, or min IFR altitude until reaching recovery point. Transponder Change to code 7xxx

1. During Link Failure mode and prior to executing Contingency Plan, UA complies with last ATC clearance received.

2. UA Pilot communicates: time of Link Failure and 'intentions' (contingency plan) to ATC via primary or alternate communications methods.

Table 2: Details for Continue Mission policy

UAS Link Failure Procedures– **POLICY B: LAND AS SOON AS PRACTICABLE**

CASE	UA Autonomy	Mission	Stratum	Link Failure Procedures
ACCESS 5 STEP ONE				
B1	Fully Autonomous – autoland capable.	Loiter/Orbit	Enroute	<ul style="list-style-type: none"> ▪ Time: 0:00 Link Interruption Mode Starts ▪ Time: 1:00 Link Failure Mode Starts¹– ATC Advised² ▪ Time: 16:00 Execute Contingency Plan: Discontinue loiter/orbit, rejoin filed route and proceed to recovery point without further loiter/orbits. Maintain higher of: last assigned altitude, or minimum IFR altitude until reaching recovery point. Transponder Change to code 7xxx
B2	Fully Autonomous –autoland capable.	Point-to-Point	Enroute	<ul style="list-style-type: none"> ▪ Time: 0:00 Link Interruption Mode Starts ▪ Time: 1:00 Link Failure Mode Starts¹– ATC Advised² ▪ Time: 16:00 Execute Contingency Plan: Comply with 91.185. Transponder Change to code 7xxx
B3	Non autoland capable.	Loiter/Orbit	Enroute	-same as for Case B1
B4	Non autoland capable.	Point-to-Point	Enroute	-same as for Case B2
ACCESS 5 STEPS, TWO, THREE AND FOUR				
B5	Fully Autonomous – autoland capable.	Loiter/Orbit	Terminal	<ul style="list-style-type: none"> ▪ Time: 0:00 Link Interruption Mode Starts ▪ Time: 0:10 Link Failure Mode Starts¹– ATC Advised² ▪ Time: 15:10 Execute Contingency Plan: Discontinue loiter/orbit, rejoin filed route and proceed to recovery point without further loiter/orbits. Maintain higher of: last assigned altitude, or minimum IFR altitude until reaching recovery point. Transponder Change to code 7xxx
B6	Fully Autonomous – autoland capable.	Point-to-Point	Terminal	<ul style="list-style-type: none"> ▪ Time: 0:00 Link Interruption Mode Starts ▪ Time: 0:10 Link Failure Mode Starts¹– ATC Advised² ▪ Time: 15:10 Execute Contingency Plan: Comply with 91.185. Transponder Change to code 7xxx
B7	Non autoland capable.	Loiter/Orbit	Terminal	-same as for Case B5
B8	Non autoland capable.	Point-to-Point	Terminal	<ul style="list-style-type: none"> ▪ Time: 0:00 Link Interruption Mode Starts ▪ Time: 0:10 Link Failure Mode Starts¹– ATC Advised² ▪ Time: 3:10 Execute Contingency Plan: Maintain present heading for 3 min then proceed direct to recovery point. Maintain higher of: last assigned altitude, or minimum IFR altitude until reaching recovery point. Transponder Change to code 7xxx

1. During Link Failure mode and prior to executing Contingency Plan, UA complies with last ATC clearance received.

2. UA Pilot communicates: time of Link Failure and ‘intentions’ (contingency plan) to ATC via primary or alternate communications methods.

Table 3: Details for Land as Soon as Practicable policy

As the NAS Group explored the policy issues raised by the detailed notional procedures above, we wrestled with the following open questions that need further study:

1. Given the wide range of UAS capabilities and missions, what is the minimal set of standardized Lost Link procedures to ensure safety and minimize adverse impact to the NAS?
2. What are the policy issues in prescribing the interval between Link Interruption and Link Failure?
3. What are the policy issues in prescribing the interval between Link Failure and execution of the UA's Link Failure Contingency Program?
4. What should be the criteria and standards for determining when a UAS with Link Failure should continue its mission versus land as soon as practicable?
5. What are the impacts of various degrees of UA autonomy and the phases of flight on Link Failure procedures?

Appendix 4 Paths Not Taken

This appendix contains brief narrative descriptions of issues and concepts that were explored but were not included in the recommendations, and the reasoning behind not including these ideas.

Note 1. We did not consider ELOS (Equivalent Level of Safety) DSA (Detect, Sense and Avoid) capability in this analysis, for example in our discussions of Link Failure and Lost Comm. In part this was because this topic was thoroughly explored by the UAS Subgroup and reported on by them. We also set this issue aside due to our focus on Step 1 operations. Had we gotten further along our NAS Subgroup recommendations might include more references to DSA capabilities.

Note 2. We did not consider use of a Flight Termination System as we considered this system an item that would be obviated by certification requirements. As one member of the NAS group wrote, “To have a flight termination system (FTS) on a UAV cleared for flight in the National Airspace System would be a contradiction. Historically flight termination systems have been installed on systems intended for flight within defined ranges/special use airspace. The purpose was to have an independent link to bring the system down within range airspace in the event of anomalies. Implicit in the requirement was that the system had insufficient airworthiness.”

Note 3. One of the proposed options for Link Failure procedure was for the UA to be programmed to return to the point of Link Failure and hold. This option was discarded because it did not meet the criterion of guaranteeing a predictable flight path, since the exact point of Link Failure may not be known, and because holding does not necessarily either restore the Link or get the UA back to a recovery point.

Note 4. One proposal for Link Failure contingencies was to preprogram the UA with prespecified Link Failure and Lost Comm points and procedures, but not to try to change the UA’s program during the mission. The objection to this option was that compliance with ATC instructions dictates that mission plan must be changeable as conditions change (as long as the Link is functioning), for example, as “expect further clearance” instructions are given.

Note 5. A suggestion was made to put UAV traffic on a designated scope with its own controller, but this was rejected because it violates a long-standing ATC operating practices and the Access 5 requirement for seamless integration in the NAS.

Note 6. A suggestion was discussed that it might be feasible to develop an advanced computing system for the UA that, in the event of Link Failure, could hold a dialog with the ATC controller (either by voice or data exchange), get instructions, and follow them, ultimately to a recovery point. This path was not taken because the ATC controller has neither the time, the training, nor the responsibility to operate the UA, which is what this proposal amounts to.